INTERNATIONAL STANDARD

ISO 15686-1

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Buildings and constructed assets — Service life planning —

Part 1: General principles

Bâtiments et biens immobiliers construits — Prévision de la durée de vie —

Partie 1: Principes généraux

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 15686 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15686-1 was prepared by Technical Committee ISO/TC 59, *Building construction*, Subcommittee SC 14, *Design life*.

ISO 15686 consists of the following parts, under the general title *Buildings and constructed assets — Service life planning*:

— *Part 1: General principles*

— *Part 2: Service life prediction procedures*

— *Part 3: Performance audits and reviews*

— *Part 4: Data requirements*

— *Part 5: Life cycle costing*

Annexes A to F of this part of ISO 15686 are for information only.

Introduction

Service life planning is a design process which seeks to ensure, as far as possible, that the service life of a building will equal or exceed its design life, while taking into account (and preferably optimizing) the life cycle costs of the building. This part of ISO 15686 provides a methodology for forecasting the service life and estimating the timing of necessary maintenance and replacement of components. It thereby provides a means of comparing different building options. It also allows for checking that performance is not unacceptably reduced to meet budgetary constraints during design development.

This part of ISO 15686 is intended primarily for:

— building owners and users;

— design, construction and facilities management teams;

— manufacturers who provide data on long-term performance of products;

— maintainers of buildings;

— valuers of buildings;

— insurers of buildings;

— technical auditors of buildings;

— those who develop or draft product standards.

It includes an introduction to predictions of long-term performance based on exposure and performance evaluation and estimates based on applying factors to adjust a reference service life, but it does not deal in detail with forecasts based on demonstrated performance or modelling of performance. However, judgements based on either of these techniques may provide important inputs to a factored estimate of service life.

A major impetus for production of this part of ISO 15686 has been concern over industry's need to forecast and control the cost of building ownership, because a high proportion of the life cycle costs of a building may be set by the time the building is complete. Where there is a large stock of older buildings, more than half of all construction expenditure is spent on maintenance and refurbishment (see annex A for details of typical maintenance costs in the UK and USA). For countries currently developing their building stock, the risk is that a similar pattern will occur if long-term performance is not taken into account at the outset.

Service life planning aims to reduce the costs of building ownership. An assessment of how long each part of the building will last, helps to decide the appropriate specification and detailing. When the service life of the building and its parts are estimated, maintenance planning and value engineering techniques can be applied. Reliability and flexibility of use can be increased and the likelihood of obsolescence reduced.

Five parts to this International Standard are planned, and work on drafting these has commenced. They will provide comprehensive guidance on the forecasting and assurance of the service life of building components and assemblies. Figure 1 shows how each part of ISO 15686 relates to the other parts, and to associated topics and other International Standards.

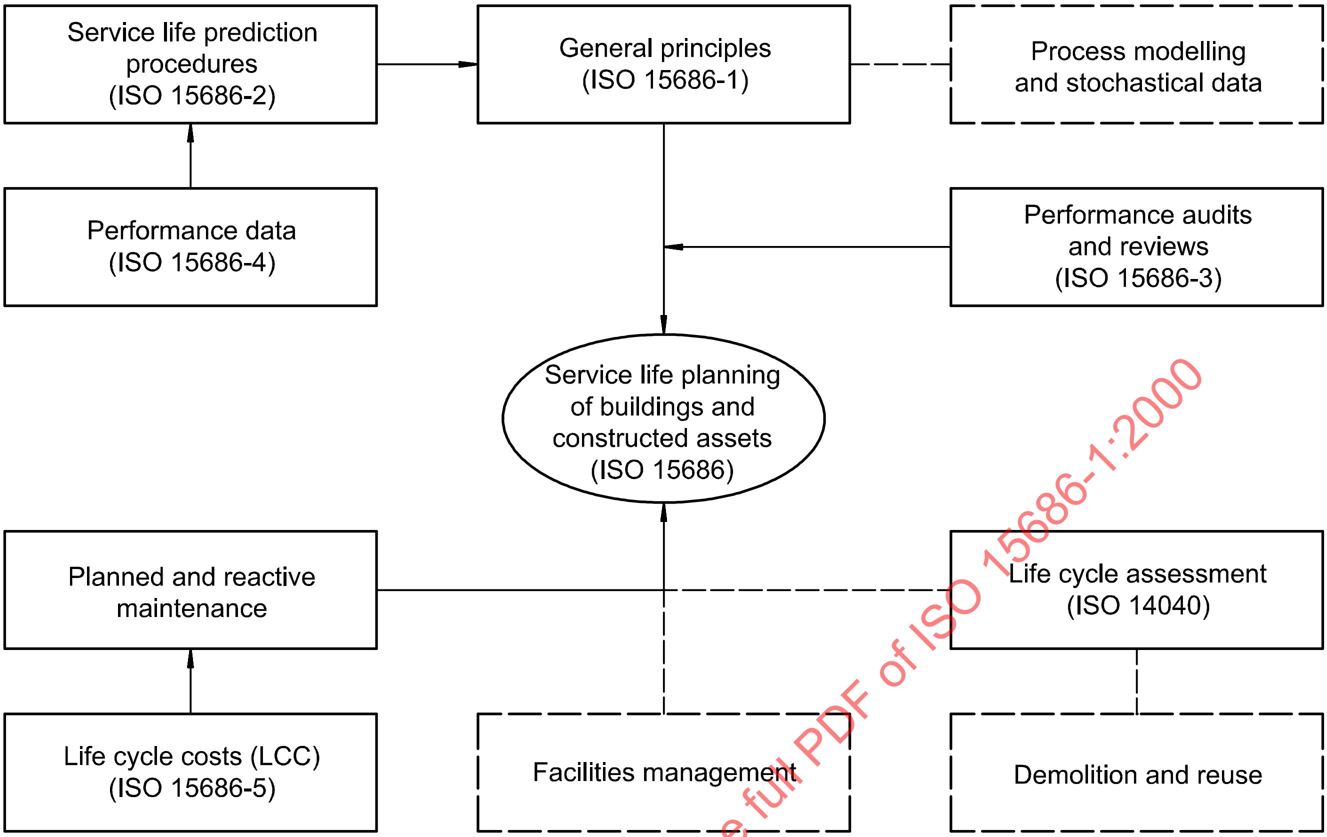


Figure 1 — Inputs and influences on service life planning of buildings

This part of ISO 15686 deals with the general principles, issues and data needed to forecast service lives, and gives a method of estimating the service life of components or assemblies for use in specific building projects. It can be used as a stand-alone document.

Part 2 of ISO 15686 describes a generic methodology for testing the performance over time of components and assemblies to provide a service life prediction. Wherever possible the reference service life used in producing an estimated service life should be derived from service life predictions as described in ISO 15686-2. Some guidance may also be given on values to assign to factors. It is anticipated that materials specialists and test houses who need to interpret or design performance tests will be the major users of ISO 15686-2.

Part 3 of ISO 15686 will describe the approach and procedure to be applied to prebriefing, briefing design, construction and, where required, the life care management and disposal of buildings and constructed assets to provide a reasonable assurance that the measures necessary to achieve performance over time will be implemented.

Part 4 of ISO 15686 will describe the range of data requirements that will allow the service life to be determined.

Part 5 of ISO 15686 will provide guidance on assessment of the life cycle costs of a building.

Additional parts are being considered.

Figure 2 shows the main topics covered in this part of ISO 15686, and where they are covered. Issues briefly introduced here, such as the calculation of costs over time (see clause 10), and quality control and reliability of estimates and forecasts (in clause 6), will be developed in later parts of ISO 15686. In the long term it is expected that a consistent application of service life planning will encourage the gathering of useful data and allow the development of computer-integrated knowledge systems for building design and maintenance.

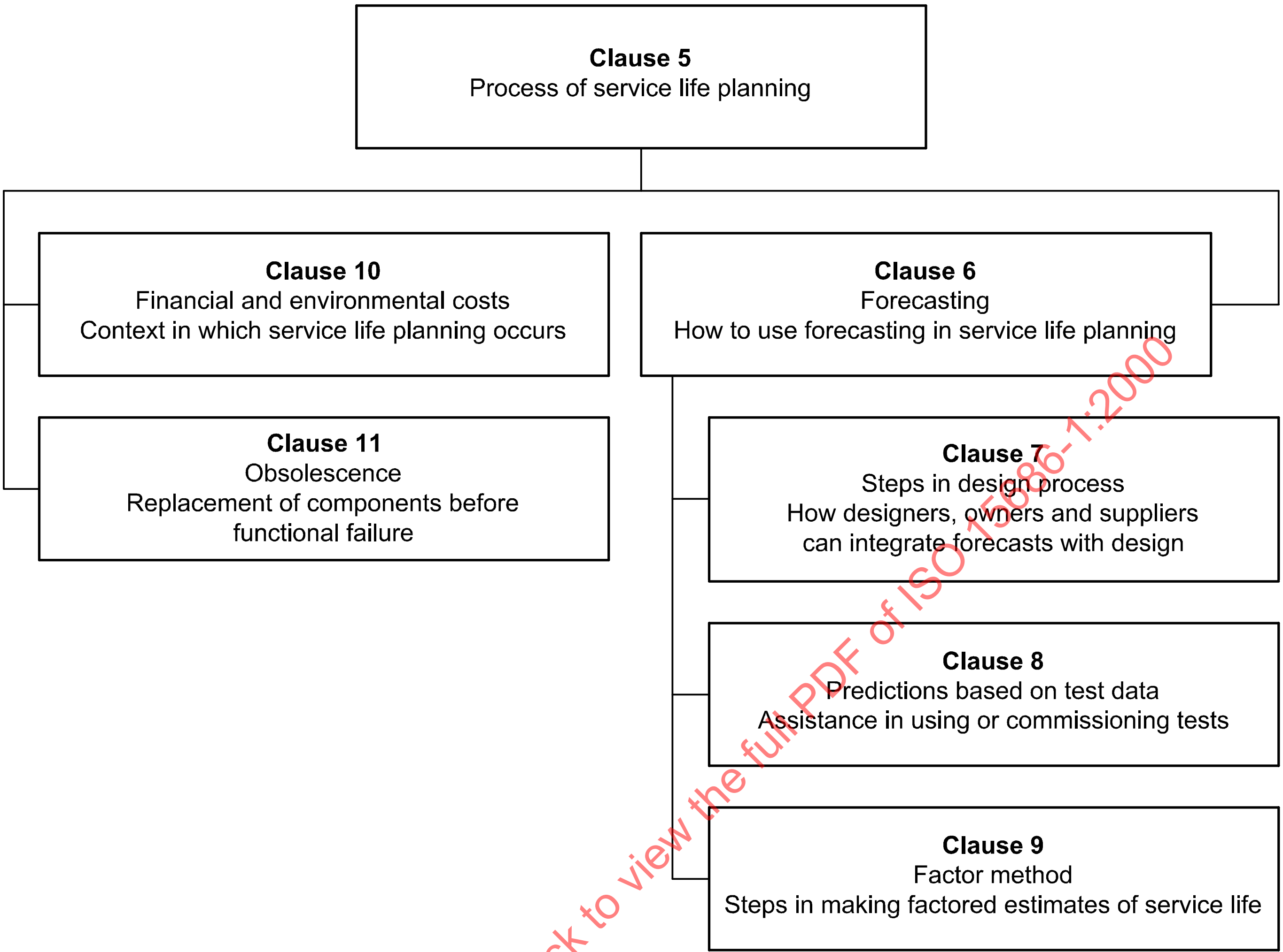


Figure 2 — Overview of this part of ISO 15686

Although not dealt with in any detail in this part of ISO 15686, the issues of performance of buildings and safety are clearly linked. When assessing future performance, priority should be given to ensuring performance at all times continues to meet national building legislative requirements for safety. It should also be noted that many local building codes already require inaccessible components or assemblies to remain functional throughout the service life of the building. In the European Community, the Construction Products Directive includes a requirement that the "essential requirements" of construction products should be retained for an “economically reasonable working life”, if necessary by maintenance.

Service life planning can be applied to both new and existing buildings. However, in existing buildings the assessment of components and detailing will apply principally to the residual service life of items that are already installed. The selection of components and detailing will only apply to repairs and new work.

The informative annexes to this part of ISO 15686 are intended to provide supplementary information and to illustrate the use of methods described in the normative clauses. The range of climatic conditions and building techniques throughout the world requires that separate factors for service life planning are developed for specific circumstances. It may be necessary to have factors that apply regionally within countries and to modify these figures to take account of locality and micro-climate.

NOTE The factor method of forecasting service life is an empirical means of methodically estimating the effect on service life of variables, using the information available. It therefore is not as precise or objective as a prediction based on scientific observations of performance over time, but it will frequently be the only means of taking all relevant factors into account within the project timescale. National development will highlight any difficulties with applying this methodology, which is innovative, and it will be reviewed in future versions of this International Standard.

The approach to service life planning adopted in this International Standard is based on the work of CIB and RILEM, and on practical studies in many countries, in particular standards published in the UK, Japan, Canada and the USA.

Buildings and constructed assets — Service life planning —

Part 1: General principles

1 Scope

This part of ISO 15686 describes the principles and procedures that apply to design when planning the service life of buildings and constructed assets. It is important that the design stage includes systematic consideration of local conditions to ensure, with a high degree of probability, that the service life will be no less than the design life.

This part of ISO 15686 is applicable to both new constructions and the refurbishment of existing structures. However, additional considerations may apply to existing buildings.

NOTE 1 In historic buildings even new work may be ruled by the need to preserve authenticity and certain options may not be available or advisable. They are therefore excluded from specific consideration within this part of ISO 15686.

NOTE 2 The skill and expertise of the person or organization undertaking the service life planning will be crucial to the reliability of the planning. Ideally a team of people who have the necessary skills in service life forecasting, design, construction and maintenance management will be represented within the project team. Familiarity with in-use conditions and construction conditions for the type of project will be of great assistance in determining typical conditions. Familiarity with the area will assist in identifying environmental factors which may not occur to strangers to the area. It is particularly important to consider local agents. These may include agents of degradation (e.g. emissions from a local power station).

NOTE 3 Wherever the term “buildings” is used in the text it should be read as “buildings and constructed assets”. Constructed assets covers everything that is constructed or results from construction operations.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 15686. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15686 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6707-1:1989, *Building and civil engineering — Vocabulary — Part 1: General terms*.

3 Terms and definitions

For the purposes of this part of ISO 15686, the terms and definitions given in ISO 6707-1 (some of which are repeated below for convenience) and the following apply. The following list is ordered by concepts, for the assistance of users of this part of ISO 15686. An alphabetical index of terms is included.

3.1 Service life and performance

3.1.1
service life
period of time after installation during which a building or its parts meets or exceeds the performance requirements

3.1.2
reference service life
service life that a building or parts of a building would expect (or is predicted to have) in a certain set (reference set) of in-use conditions

3.1.3
estimated service life
service life that a building or parts of a building would be expected to have in a set of specific in-use conditions, calculated by adjusting the reference in-use conditions in terms of materials, design, environment, use and maintenance

3.1.4
design life
intended service life (deprecated)
expected service life (deprecated)
service life intended by the designer

EXAMPLE As stated by the designer to the client to support specification decisions.

3.1.5
predicted service life
service life predicted from recorded performance over time

EXAMPLE As found in service life models or ageing tests.

3.1.6
forecast service life
service life based on either predicted service life or estimated service life

3.1.7
service life planning
service life design (deprecated)
preparation of the brief and design for the building and its parts to achieve the desired design life, for example in order to reduce the costs of building ownership and facilitate maintenance and refurbishment

3.1.8
residual service life
service life remaining at a certain moment of consideration

3.2 Degradation and exposure

3.2.1
ageing test
combination of ageing exposure and performance evaluation used to assess changes in critical properties for the purpose of service life prediction

3.2.2
(degradation) agent
whatever acts on a building or its parts to adversely affect its performance

EXAMPLES Person, water, load, heat.

3.2.3
degradation mechanism
chemical, mechanical or physical path of reaction that leads to adverse changes in a critical property of a building product

3.2.4
degradation
deterioration (deprecated)
changes over time in the composition, microstructure and properties of a component or material which reduce its performance

3.2.5
durability
capability of a building or its parts to perform its required function over a specified period of time under the influence of the agents anticipated in service

NOTE Durability is not an inherent property of a material or component, although the term is sometimes erroneously used as such.

3.2.6
exposure in experimental buildings
long-term exposure of items in special buildings where the conditions may be monitored and in some cases controlled

3.2.7
field exposure
long-term exposure of items at special locations with known environmental conditions (agents)

3.2.8
long term *in-situ* exposure
long-term exposure of items deliberately incorporated in buildings

3.2.9
short-term in-use exposure
short-term exposure in which the intensities of agents are at levels expected in service

3.2.10
ageing
degradation due to long-term influence of agents related to use

3.3 Performance

3.3.1
failure
loss of the ability of a building or its parts to perform a specified function

3.3.2
performance evaluation
evaluation of critical properties on the basis of measurement and inspection

3.3.3
performance
performance in use
qualitative level of a critical property at any point of time considered

3.3.4
performance requirement
performance criterion
minimum acceptable level of a critical property

3.3.5
performance characteristic
property that is expected to be associated with a material quantity, being a measure of an initial property or a magnitude of that quantity

3.3.6
performance over time
description of how a critical property varies with time

3.3.7
property
inherent or acquired attribute of an item

3.3.8
property measurement test
test to determine the value of a property

3.3.9
critical property
essential property (deprecated)
property of a building or a building part that has an acceptable value if its required function is to be fulfilled

3.3.10
condition
level of critical properties of a building or its parts, determining its ability to perform

3.3.11
defect
fault, or deviation from the intended level of performance of a building or its parts

3.3.12
obsolescence
loss of ability of an item to perform satisfactorily due to changes in performance requirements

3.4 Parts of buildings

3.4.1
building
construction works that has the provision of shelter for its occupants or contents as one of its main purposes and is usually enclosed and designed to stand permanently in one place

3.4.2
(building) product
Item manufactured or processed for incorporation in construction works

3.4.3
(building) assembly
set of components used together

3.4.4
(building) component
product manufactured as a distinct unit to serve a specific function or functions

[ISO 6707-1]

3.4.5
(building) material
substance that can be used to form products or construction works

[ISO 6707-1]

3.4.6
(building) sub-component
manufactured product forming part of a component

3.5 Maintenance activities

3.5.1
repair
return of a building or its parts to an acceptable condition by the renewal, replacement or mending of worn, damaged or degraded parts

NOTE Based on definition given in ISO 6707-1 but "degraded" used rather than "decayed".

3.5.2
maintenance
combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions

3.5.3
refurbishment
rehabilitation (deprecated)
renovation (deprecated)
modification and improvements to an existing building or its parts to bring it up to an acceptable condition

3.5.4
restoration
actions to bring an item to its original appearance or state

3.6 Acts and actors

3.6.1
brief
working document which specifies at any point in time the relevant needs and aims of a construction project, resources to be provided by the client, the details of the project and any appropriate design requirements within which all subsequent briefing (when needed) and designing can take place

3.6.2
client
person or organization that requires a building to be provided, altered or extended and is responsible for initiating and approving the brief

3.6.3
constructor
contractor (deprecated)
person or organization that undertakes construction work

3.6.4
designer
person or organization responsible for stating the form and specification of a building or parts of a building

3.6.5
manufacturer
person or organization that manufactures buildings or parts of buildings

3.6.6
supplier
person or organization that supplies buildings or parts of buildings. The supplier may also be the manufacturer

3.6.7
user
person, organization or animal for which a building is designed (including building owner, manager and occupants)

3.7 Other terms

3.7.1
environment
natural, man-made or induced external and internal conditions that may influence performance and use of a building and its parts

3.7.2
environmental condition
state of a characteristic of the environment

3.7.3
incompatibility
detrimental chemical and/or physical interactions between materials and/or components which lead to premature degradation

3.7.4
factor method
modification of reference service life by factors to take account of the specific in use conditions

3.7.5
life cycle cost
total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value

4 Abbreviated terms

DL	design life
DLB	design life of a building
DLC	design life of a component (or assembly)
ESLB	estimated service life of a building
ESLC	estimated service life of a component (or assembly)
PSLC	predicted service life of a component (or assembly)
RSLB	reference service life of a building
RSLC	reference service life of a component (or assembly)

5 Process of service life planning

5.1 General

This clause gives an overview of the issues which should be considered in planning to help ensure the service life of the building.

5.2 Forecasting

The objective of service life planning is to assure, as far as possible, that the estimated service life of the building or component will be at least as long as its design life (i.e. ESLB or ESLC will equal or exceed DLB or DLC). As the length of service life cannot be known precisely in advance, the objective becomes to make an appropriately reliable forecast of the service life using available data. The purpose for most clients will be to ensure that the most advantageous combination of capital, maintenance and operational costs is achieved over the life of the building. The output of service life planning will be a series of predicted service lives of components, and a projection of maintenance and replacement needs and timings.

Achieving this may, of course, require maintenance during the service life of the building and/or the component. Estimation of the service life at the design stage allows consideration of the specific site. It will assist planning of future maintenance operations, selection of the optimum specification and design, and avoidance of waste.

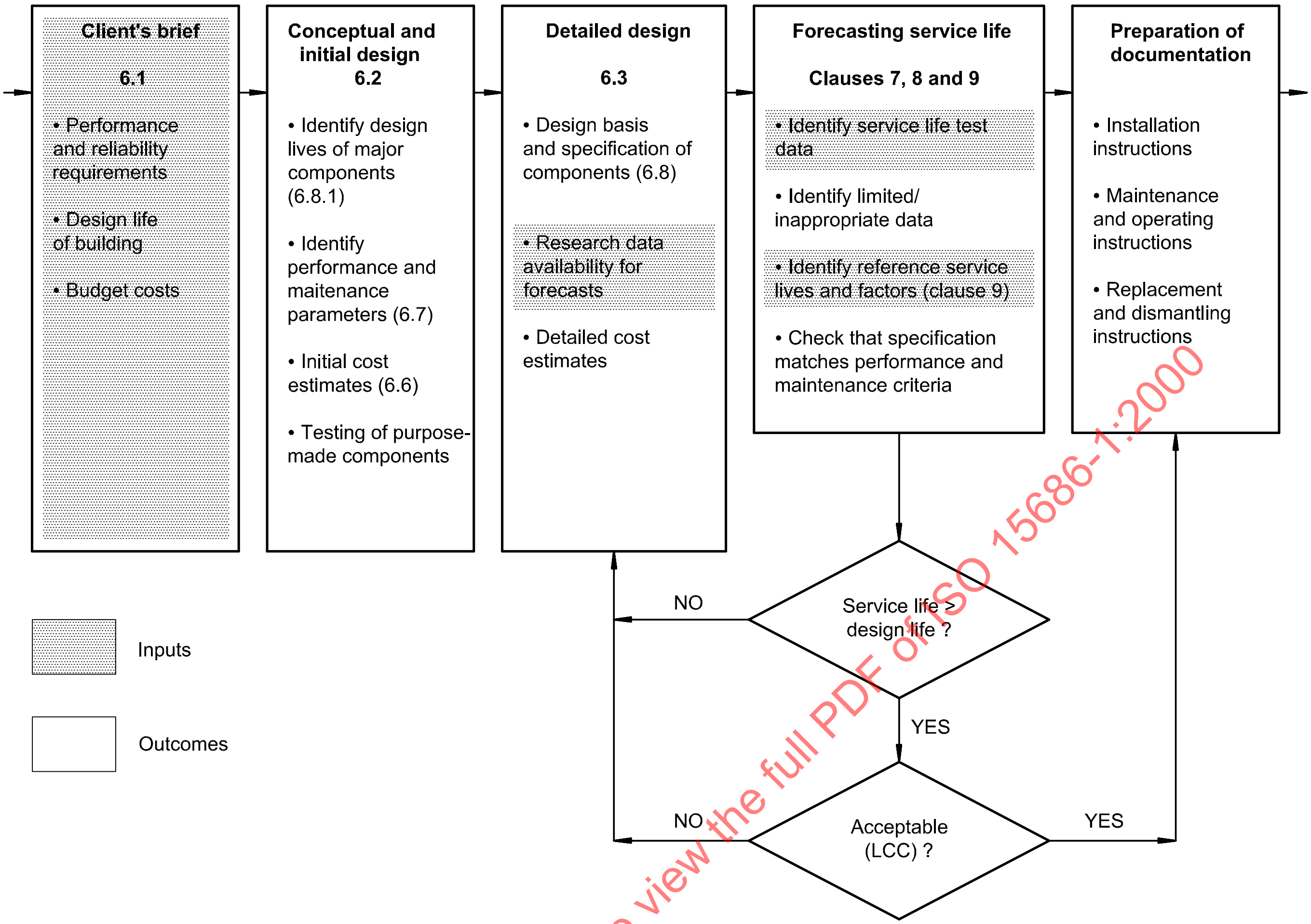
The process of service life planning can be applied to both existing buildings and new constructions. For existing buildings and components, many of the choices have been predetermined, and the building is already some way through its service life, and therefore planning the service life will focus on assessing the residual service life of components and optimizing programming and costs of replacements. This part of ISO 15686 therefore focuses on planning the service life of new buildings and components.

Service life planning involves consideration of the likely performance of the building over the whole of its life under the environmental conditions applicable to it, from conception through to operation and maintenance. Future repairs, removal, reuse, dismantling and disposal should be considered at the design stage. For very long design lives (e.g. for important state buildings), ease of maintenance is likely to determine the service life. If the service life of an essential component is less than the design life of the building, it should be replaceable or maintainable.

Service life planning should be integrated into the building design process. Figure 3 indicates how service life forecasting fits into a typical design process. Depending on the contractual arrangements, the person responsible for each task may vary. However, the contractual arrangements should reflect the tasks to be carried out, and responsibility at each stage should be given to an appropriate party. Figure 3 provides a model which can be adapted as necessary to meet the needs of particular contractual arrangements.

Figure 3 demonstrates that service life planning may involve iterative assessments of design to identify which aspects adequately meet the performance and maintenance requirements, while also having acceptable costs. It also emphasizes the importance of commencing testing of purpose-made components early so that initial results can be compared with requirements in the brief.

The final stage of the process involves communicating the results of service life planning to parties who will occupy and maintain the building. They need to be aware of assumptions made about the in-use environment and anticipated maintenance to achieve the estimated service lives.



NOTE Numbers refer to clauses within this part of ISO 15686.

Figure 3 — Process of service life forecasting related to design stage

6 Service life planning: Steps in the design process

6.1 The brief

Decisions critical to the service life are taken at the earliest stages of design. The design stage should include full consideration of local conditions, thus ensuring, with a high degree of probability, that the service life will be no less than the design life.

At this stage the fundamental objectives to be met in planning the service life should be established. These include the following:

— the design life of the building and the functional performance required from the building components over its design life;

— measurable functional performance criteria and unacceptable functional performance that may require replacements of components;

— which building components or assemblies need to be repairable/maintainable/replaceable within the design life of the building.

Typically these decisions should be made by the owner and designer at an early stage in the briefing process.

NOTE The client should ideally provide well-defined and comprehensive requirements for the building in the brief. However, there may be occasions where ambiguities, deficiencies or conflicts in the brief require clarification. These might include requirements for minimal maintenance or whole-life costs that could be misinterpreted or lead to unacceptable initial costs.

6.2 Conceptual and initial design

While making initial design choices, professional judgement and expertise will be required to check the following.

— Whether the design life of the building is achievable within the project constraints (e.g. budget, time, performance, maintenance requirements and site-specific issues).

— Whether the design meets the performance requirements defined in the brief by the client (e.g. for non-replaceable components).

— Whether allowance has been made for replacement, maintenance and/or upgrading to avoid undue disruption to the use of the building. Note that many local building codes require inaccessible components to have a service life at least as long as the design life of the building.

As a result of these checks, it may be necessary to review the brief, or to modify initial designs.

6.3 Detailed design

Detailed design includes selection of materials and components. Since it is rare for components to be designed as prototypes for a specific building, choices may be limited by the availability of component design and materials. At this stage there will frequently be an iterative process of proposing a component, checking its predicted performance against the brief, and amending selections if required.

NOTE Communication between component suppliers and the designer will help to identify which agents will be relevant and whether the component is suitable. Component suppliers should receive as much information about the intended end-use as possible. Ideally the assessments described in 6.5 and 6.8 should be provided to them (perhaps in summary form).

As part of service life planning, components should be assessed for compliance with performance requirements. Performance will deteriorate at a rate depending on

— the environment, including the reactions at interfaces between materials and/or components,

— the design of the building, the component and installation detailing,

— the materials,

— the skill and quality of sitework,

— maintenance, and

— usage.

Responsibility for interface design should be clearly identified as it is critical to performance. The design of the rest of the building determines the environment of each component considered, and neighbouring materials are part of the environment (see ISO 6241 for further details). However, specific references have been made to interfaces through this part of ISO 15686 as they are frequently not taken into account in data used for assessing component performance.

6.4 Specification

6.4.1 General

Specification may be considered to be part of detailed design, but is dealt with here separately. It includes selecting appropriate component specifications and installation details, and may extend into selecting the optimum specifications, using techniques such as value engineering or life cycle costing. The specification should include measurable/auditable performance criteria. (This will be dealt with in greater detail in ISO 15686-3.) Subclauses 6.4.2 to 6.4.4 describe some of the most important issues for service life planning.

NOTE Specification concerns many issues other than the service life of the building and its components.

6.4.2 Installation detailing

The installation detailing and interfacial environment can be adjusted by design to offer protection against agents of degradation and/or avoidance of their effects.

NOTE Strategies may include provision of overhanging projections, site-applied coatings or layers, removal of aggressive agents in the ground, isolation layers, ventilation, etc.

6.4.3 Material and component selection

Materials and components vary in their reaction to agents of degradation and therefore some materials may be unsuitable even on an initial inspection. It is not necessary to go through all possible options to demonstrate this. Test data from the manufacturer and others should be used to identify suitable materials, but may not be available for all relevant agents (as described in 7.2.2). Component designs may also alleviate effects of agents (e.g. by incorporating sacrificial/protective layers) or may aggravate them (e.g. by permitting contact between incompatible materials).

EXAMPLE Macroenvironment level consideration of a project may indicate that the most aggressive local agent is the salt spray in a marine environment. Readily available test data may indicate that lightly galvanized mild steel is unsuitable without detailed consideration of the specification. Specification therefore proceeds with that option ruled out, but includes the possibility of a plastic-coated steel. Choosing a suitable metal or non-metallic alternative may, however, require more detailed research or testing that takes account of other local agents.

Manufacturers generally have quite detailed knowledge of the performance characteristics of the products they supply. However, without detailed knowledge of the performance requirements (described in 6.8) and agents which characterize the local environment (see 7.2.2), they may not be able to input reliable data for forecasting service lives. The results of the discussions and analysis of the local environment and client requirements should be communicated to them. The maintenance requirements of the selected components should also be checked for compliance with the brief.

It is important for designers to achieve an acceptable balance between the use of familiar materials and components, whose performance is known through test data and/or experience, and innovative ones which may achieve better performance than traditional specifications but may lack service life data.

6.4.4 Site work

If local conditions, environment during construction, materials, skills and levels of workmanship do not achieve the manufacturer's recommendations or codes' workmanship standards, the effect on the service life should be considered. It may be possible to reduce the risks of workmanship defects or limit use of unreliable materials.

A margin of error should be allowed whenever less than perfect conditions can be anticipated. It may be difficult on site to achieve the specified conditions needed for construction (e.g. for the moving of materials, construction of fine tolerance or application of coatings and sealants). The problems may be avoided by shifting fabrication from site to factory or use of familiar components, more tolerant of different installation conditions.

NOTE No matter how good the design is, if unauthorized alterations and/or substitutions occur on site some or all of the benefits of the service life planning may be lost.

6.5 Environmental characterization

The environment within and around each building is unique. Environmental characterization can be at a general level or in detail, depending on its criticality and the data available. The purpose of characterizing the environment is to identify which agents are relevant and their likely effects. The average intensity/concentration/level of degradation agents, and frequency of cycling between states (e.g. cycling from wet to dry, through freezing points, maximum and minimum daily temperatures, frequency of exposure to salt spray, etc.) is relevant to the dose of the agent, and forms part of the characterization of the environment. Note that in some cases stable extreme conditions cause less deterioration than frequent cycling between states. This is typical for freeze-thaw conditions.

Annex C contains a list of environmental agents which may cause degradation. More detailed guidance is included in ISO 15686-2.

This assessment should only need to be done once for each project. However, several locations may need to be considered separately if they have different microenvironments. Identifying these areas will depend on which agents are relevant to each. This list given below is not intended to be complete but to indicate the type of locations which may need separate consideration. For many buildings one external assessment and two internal assessments (for dry and wet areas) may be all that is required. Examples include the following:

a) specific locations: the exposed building envelope will be more exposed than semi-sheltered internal locations; the microenvironment all over a building will vary and on very high buildings there may also be meso-environmental variations (e.g. increased water and pollutant exposure, and on high buildings, wind, on the elevation exposed to prevailing wind-driven rains);

b) components in ground contact: ground-water or soil agents;

c) communal internal areas, refuse collection points, etc : locations subject to heavy use

d) locations subject to unusual agents, such as blood, oil, phenols, chlorides, milk, acids or any local particularly aggressive agents; these may be due to local industrial processes (e.g. degradation agents from reactions producing nitrogen oxides and sulfur dioxide);

e) locations subject to condensation, such as sub-floor voids, window reveals and roof voids;

f) locations subject to wetting, such as kitchens, bathrooms, pools (e.g. through rain, cleaning, condensation and splashing);

g) locations subject to aggressive maintenance: de-icing, bleaches and graffiti removal;

h) locations with differing uses, such as operating theatres, hospital wards and corridors;

i) locations where maintenance will be unlikely, such as high level, inaccessible and confined areas.

6.6 Initial cost estimates

Design should reflect the constraints of the budget for the overall project. To meet the brief, adjustment of either the budget or the service life requirements may be necessary. Where a specification is adjusted to meet cost constraints, the maintenance implications should also be considered.

NOTE The most obvious way to reduce initial costs (by altering to a lower specification component) may increase maintenance requirements over the life of the building, which may be unacceptable to the client. Clause 10 indicates some of the relevant considerations if costs over the life of the building are to be taken into account, but this subject will be dealt with in detail in ISO 15686-5.

6.7 Maintenance plan

Maintenance is defined very broadly for this part of ISO 15686 to include both cyclical maintenance (such as regular redecoration), reactive condition-based maintenance (repairs of defective performance) and major refurbishment. Planning the service life of the building will naturally lead to production of a schedule of planned dates for replacements of components, and this can be extended if required to indicate likely dates for major refurbishment and replacement of subsidiary parts of assemblies (such as door and window hardware, seals and glazing to windows, flashings to roofs, etc.). Part of planning the service life is to consider the appropriate service life for each component with its sub-components. This allows rationalization of maintenance activities and costs. This subject will be dealt with in ISO 15686-5.

The estimated service lives and maintenance/replacements of components should be communicated to the owner, user or client. This will help maintainers by indicating future operations and cyclical maintenance which were anticipated at the design stage. It should also alert them to agents (e.g. cleaning agents) which were not anticipated by the designer. It may also be extended to provide cost plans for maintenance. However, not all maintenance can be foreseen and planned, and some provision should therefore be made for unforeseen costs.

Maintenance activities which can be reasonably anticipated, and which should be taken into account in planning the service life of the building, include the following:

a) change of interior finishes (including both decorative finishes and, for example, retiling during works to kitchens and bathrooms);

b) removal/change of partitioning (particularly in offices);

c) change of roof weatherproofing (the likelihood of this will vary with the design life of the building and the type of covering);

d) replacement and change of electrical, plumbing or other service installations (this is highly probable for most types of building);

e) alterations to below-ground drainage (relatively rare; normally occurs following extensions or change of use);

f) partial removal or replacement of load-bearing elements (normally during refurbishment or replanning).

Assumptions made in service life planning should be recorded for future reference. Forecasts of service lives may be invalidated by changes or activities which take place during the service life of the building.

Local building codes may also require the designer to consider future maintenance requirements and safety.

6.8 Performance requirements and acceptability

6.8.1 Permanent, replaceable or maintainable construction

Buildings and their components and assemblies should be identified as being either replaceable or permanent. Building components will often need replacement or maintenance during the service life of the whole building. It may be uneconomic, or impossible or not functionally desirable to require all components to retain acceptable performance without maintenance for a typical building with a design life of many years.

NOTE 1 The most likely exceptions are structural components or assemblies (such as foundations, frames or embedded fixings) which are so disruptive to maintain or replace that their failure may trigger replacement of the building. The feasibility of safely demolishing the building or component and disposing of waste may also be relevant.

NOTE 2 For temporary buildings it is generally desirable to match the design lives of components to that of the whole building. Ease of disassembly will aid recycling or reuse.

NOTE 3 Buildings with very long design lives may need continual repair and replacement to achieve their design lives. Thus, ease of disassembly and reassembly to retain the existing building fabric may be a design objective, together with the facility of repair without causing damage.

Table 1 gives suggested minimum design lives of components for particular design lives of buildings, based on their accessibility for maintenance. It is included to give a starting point for discussions about appropriate design lives, but should not inhibit choice of design lives for appropriate economic reasons (e.g. to match replacement cycles to the design life of the building, or where components with the suggested durability might be excessively costly or unavailable, such as rainscreen overcladding with a design life of over 25 years).

Table 1 — Suggested minimum design lives for components (DLC)

Design life of building	**Inaccessible or structural components**	**Components where replacement is expensive or difficult** (incl. below ground drainage)	**Major replaceable components**	**Building services**
Unlimited	Unlimited	100	40	25
150	150	100	40	25
100	100	100	40	25
60	60	60	40	25
25	25	25	25	25
15	15	15	15	15
10	10	10	10	10

NOTE 1 Easy to replace components may have design lives of 3 or 6 years.

NOTE 2 An unlimited design life should very rarely be used, as it significantly reduces design options.

6.8.2 Performance limited by degradation

For service life planning, the service life of a building is limited by the degradation of its non-replaceable components. Degradation in itself does not necessarily require component replacement, unless it results in unacceptable performance and repair is not economically justifiable. The service life of a building may also be limited by degradation of replaceable or maintainable components or assemblies when such maintenance or replacement results in major costs, safety issues or disruption in use.

Service life planning is concerned with foreseeable risks, and this inevitably limits forecasting of obsolescence or replacement for reasons other than unacceptable performance. Maintenance (including replacement of sub-components and replanning) is the major strategy to counter degradation. Defective performance may also occur as a result of unforeseeable events or processes. Consideration of the consequences of foreseeable mechanisms of degradation should minimize unforeseen replacements (which are often caused by inadequate visualization of future demands on the building).

6.8.3 Acceptability

Performance requirements are set by the client as part of the design brief. Some may be imposed by local building codes or regulations. The building or a component may require replacement or repair if these requirements are no longer met.

Early in the design process it is important to identify the minimal acceptable levels of critical properties of important components. These properties determine the aspects of performance which may trigger replacement of a component if the component ceases to meet the acceptable levels (due to its failure to perform an essential function). Defective performance may end the component’s service life (unless economic maintenance or repair can restore performance). The rest of the process of service life planning consists of estimating how long it will take for a component to reach the level of unacceptable performance. It is also desirable to facilitate possible (anticipated) future changes.

It is important to recognize that not all reductions of properties affect critical aspects of performance. The performance of many components does not affect the acceptability of the building. However, which failures are relevant may be determined largely by the operational activities within the building.

EXAMPLE If computers are used within the building, temporary high levels of condensation may be catastrophic.

It is desirable for the owner to identify components whose performance is critical, and/or highlight potential failures which may not be obvious causes for the building to become unacceptable (e.g. uneven colour loss on cladding).

Unacceptable performance may require maintenance (e.g. cleaning, partial replacement of sub-components, repair) or replacement of the component. Replacement may also be necessary where maintenance is very costly or where repair is impossible (e.g. due to unavailability of spare parts).

EXAMPLE A window may need replacement if it ceases to do any of the following:

— remain safe and secure;
— open and close;
— be transparent;
— prevent water leaking around the frame;
— retain acceptable appearance;
— provide adequate insulation against heat losses.

NOTE Replacements may also take place due to obsolescence or to change of use of the building.

Service life planning can only address foreseeable changes.

A worked example showing typical performance requirements for a roof to domestic accommodation, and an assessment of the ability of alternatives to satisfy the requirements is given in annex B.

6.8.4 Consequences of failure

The consequences of failure may include hazards to health and safety, and it is frequently useful to categorize failures by their consequences. This allows prioritization of avoidance of component failures to be taken into account in evaluating their service lives on the basis of avoiding unacceptable risks to health and safety or other considerations critical to building owners or users. Table 2 (modified from BS 7543) indicates a suggested hierarchy of consequences, but certain consequences may be considered more important in particular circumstances (e.g. interruption of access to a building to customers of a retail shop).

Where the consequences of failure are judged to be critical, it may be necessary to allow for a particularly long design life of the component, or enhance inspection and maintenance regimes, to reduce the risk of failure occurring within the design life of the building. This may be particularly relevant in situations where, for example, escape of a dangerous substance may occur or large numbers of people may be injured if the component fails to maintain its critical properties. Ideally this allowance should be made on the basis of stochastic approach.

Table 2 — Suggested hierarchy of safety consequences

Category	Consequence	Example
1	Danger to life	Sudden collapse of structure
2	Risk of injury	Loose stair tread
3	Danger to health	Serious damp penetration
4	Costly repair	Extensive scaffolding required
5	Costly because repeated	Window hardware replacement
6	Interruption of building use	Heating failure
7	Security compromised	Broken door latch
8	No exceptional problems	Replacement of light fixtures

6.8.5 Functional acceptability

This includes (but is not limited to) acceptable performance requirements in areas related to health, safety, utility or property protection. Examples are given in annex D.

6.8.6 Economic acceptability

Normally, replacements justified on economic grounds indicate that better performance is available from new components or because maintenance or repair is unacceptably costly. Examples of replacements for economic reasons are included in annex B.

7 Service life forecasting

7.1 Introduction to forecasting

7.1.1 Objective of forecasting

The objective of forecasting the service life of a building or a component is to establish whether it can be expected to exceed the required design life with adequate reliability. Forecasts of service life should

— reduce uncertainty,

— seek to use available data of known quality,

— take account of variability and

— be used to guide rather than dictate.

A forecast service life is referred to as the ‘predicted service life’ if it is based on the procedures outlined in clause 8 (and described in more detail in ISO 15686-2) which usually involve tests. If the predicted service life or another source of information is used to provide a reference service life, it can be adjusted to reflect local, project-specific factors using the factor method described in clause 9. It is then referred to as the “estimated service life”. Other methods of obtaining a forecast value of service life are likely to become available, and the source of the reference service life should be clearly identified. When practicable, a forecast based on appropriate, complete test data (i.e. where all the factor values are 1) should be used in preference to less accurate sources.

A forecast should, wherever possible, be reliable clear and cautious. However, data at present are rarely available or comprehensive enough to indicate reliably the degradation of even very similar buildings or components, since in practice there are many variables which affect service life. A method that establishes a forecast of service life is therefore needed to make use of all available data (and to identify missing data). This is given in clause 9. Where data required for forecasting are incomplete, the forecast should be cautious and the reasons for caution noted. It may subsequently be possible to update the forecast. The forecast service life should always be justified in a written report.

7.1.2 Precision and reliability of forecasting

Due to the number of variables involved and the inherent variability of buildings, environments, site workmanship and future maintenance, it is rarely possible to forecast the service life as precisely and reliably as one would prefer. Depending on the data available and the necessary assumptions, the reliability of the forecasting will vary. It is therefore necessary to decide whether or how the uncertainty in the forecast service life should be taken into account in service life planning.

Generally, a lower level of reliability will be acceptable for maintainable components than for those which are intended to function without maintenance for the service life of the building. An 80 % confidence limit may be acceptable for maintainable components, while non-maintainable inaccessible components may need higher levels. Forecasts and estimates of service lives of permanent components or assemblies should therefore exceed the design life of the building by a margin to allow for errors.

NOTE As more sophisticated methods of forecasting are developed all the time, and as databases of performance and the factors which affect it are improved, so reliability will improve.

7.1.3 Use of data for forecasts

All buildings and their environments and use are unique, and therefore incomplete data will inevitably affect both the accuracy and reliability of forecasts.

It should be recognized that more extensive extrapolation (e.g. from short-term exposure data) entails more assumptions and therefore the forecast becomes less reliable.

Buildings, materials and components which are innovative pose a particular problem since forecasting is invariably based on interpretation of the known performance of dissimilar applications or on accelerated exposure alone. There may be a bias in favour of tried and trusted solutions for this reason, and it is important to recognize that innovative solutions may offer superior performance or overcome long-standing problems.

However, even where data are incomplete or there is little experience of use of the item, it should be possible to indicate a minimum period during which it is anticipated that a building or component can remain in service on the basis of stated assumptions about future events. This should be indicated in years from the date of completion of the building.

NOTE 1 Vague descriptions such as "very durable" should be avoided.

NOTE 2 The science of service life planning is relatively new, and therefore factors affecting the lives of even traditional components are not fully understood, or researched. It is therefore necessary generally to extrapolate from known data, which introduces assumptions about future performance and conditions.

NOTE 3 Data on performance at interfaces between adjacent components or materials are often omitted from testing, and yet it is known that degradation or defects such as water ingress generally commences at junctions between two or more materials and/or components. It is therefore important to try to forecast not only the material or component performance but also the effect of interfaces on the performance of the larger system.

7.1.4 Taking account of variability and reliability

Variable performance and service lives can be anticipated within any group of similar items. Opinion varies on whether a statistically normal distribution can be anticipated within a similar group of buildings or components. Assessment of accelerated exposure tests should include correlation between *in-situ* performance and laboratory results to allow prediction of future performance.

Study of failures of moving parts (termed tribology) is relatively advanced, and is generally reported as a mean time to failure. This implies that roughly equal numbers of components will fail before and after the given period of years/cycles. However, a more cautious statement of predicted or estimated service lives may be preferred, since a 50 % failure rate is likely to be much too high.

NOTE 1 High variability in performance is particularly common in construction because of the number of variables. The prevailing opinion appears to be that service lives follow a Weibull distribution, possibly modified to take account of premature failures. It is rarely possible to indicate where on the range of anticipated results a particular building or component within a very similar homogeneous group will come. Where the group is less homogeneous (e.g. all windows rather than all windows of one specification) it should be possible to indicate whether a specification falls within the higher or lower range.

NOTE 2 Under similar conditions components (e.g. bearings, moving parts and light bulbs) are known to all fail within a fairly short period of the first few failures. For this type of component there is relatively little "spread" of failures, and replacement or maintenance may be planned to follow closely on these initial failures. Some reliable data are available on performance of building services components where the primary indicator of failure is known to be the number of cycles or iterations of a particular action (e.g. lighting cycles of a lamp).

NOTE 3 There will also be some defects which occur within a very short time of occupation which may be termed "premature defects'. These do not necessarily indicate wide scale failure, but should be rectified.

7.1.5 Use of forecasts

Forecasts of service life should be viewed as indicative and decisions should be guided, but not dictated, by the results. However, service life planning is necessary if the best-informed decisions are to be made in maintenance planning, cost planning and value engineering.

NOTE For a building in service, maintenance plans may need to be modified based on the inspected condition. Updating the plan as more knowledge becomes available should be carried out.

7.2 Issues that can affect forecasting

7.2.1 Relevant issues

Whatever method of forecasting is selected, certain issues will be relevant. This subclause discusses the following critical issues:

— agents that cause degradation;

— effects of dose and intensity variations;

— effects of agents in combination.

7.2.2 Agents relevant to degradation

Annex C comprises a list of the agents of degradation which characterize the environment of the building and its components. This annex should be used to guide the broad environmental characterization described in 6.5. Agents of degradation cause degradation of various types, which reduce the performance of the building or component over time. Agents are classified in ISO 6241. Agents fall within the following general categories:

— mechanical;

— electromagnetic;

— thermal;

— chemical;

— biological.

NOTE 1 For service life planning the relevant agents cause degradation. ISO 6241 classifies agents according to their nature. Sudden failures caused by structural overloading or fire are not included within this standard but gradual loss of fire resistance or structural strength following for example fungal attack or wear are included.

Different components will be exposed to different agents (e.g. those on the building envelope and those in ground contact). All relevant agents should be identified, both internal and external, including agents which will be relevant after the building is occupied.

To determine whether an agent is relevant, it is necessary to determine whether it will initiate one of the possible degradation mechanisms of the material or component.

NOTE 2 ISO 9223 may be used to evaluate the corrosivity of atmospheres for metals and alloys under known conditions of time of wetness, pollution by sulfur dioxide and/or airborne salinity. In the same way ISO 12944-2 deals with the classification of environments related to corrosion protection of steel structures by protective paint systems (for exposure to the atmosphere, immersion in water or buried in soil).

NOTE 3 General guides to materials and components will assist in identifying relevant agents (e.g. acids for metals) but may not highlight agents relevant to interfaces or abutments (e.g. thermal movements of plastics fixed to masonry or loss of plasticizers following contact between certain plastics and bituminous materials). Experience indicates that rapid degradation often occurs at interfaces (e.g. between dissimilar metals).

7.2.3 Effects of dose and intensity variations

Once relevant agents have been identified, it is necessary to determine the dose of the agent over a reference period of time (usually a year), and in some cases the attained magnitude or rate of maximum and minimum values (e.g. minimum temperatures for a material which becomes brittle in cold conditions. This evaluation may be done at a very general level or in detail. For many components it may only be necessary to determine that the exposure to the maximum intensity will be occasional or regular.

Knowing the anticipated intensity of agents relevant to the building or component will assist in interpretation of test data. It is important to recognize that tests should be relevant to the environment under consideration (e.g. intensity of UV exposure should reflect the anticipated in-use conditions).

Satisfactory performance in for example extreme temperatures may not indicate satisfactory performance in climates with regular cycling from dry to wet, hot to cool, or through freezing points.

7.2.4 Effects of agents in combination

Agents in the built environment very rarely act alone, but rather work together and/or synergistically. The service life forecast should ideally take into account the actions of all agents concurrently, but the data for this may not be available. Therefore it may be necessary to consider only the most relevant agents and assess their effect both separately and in combination, before adjusting the results to allow for degradation caused by other agents (e.g. normal wear and tear).

7.3 Types of data used for forecasting

7.3.1 Relevant data

The availability of data for forecasting will vary, but the following types of data are relevant:

— measurement of performance over time;

— comparisons;

— experience (feedback from practice);

— expert estimations.

Data can be gathered by observing and measuring performance under long- or short-term tests, including empirical observations of similar buildings or components in the built environment. The assessment entails comparing the data gathered to that for the buildings or components under assessment.

NOTE Useful data on exposure are included within the EOTA document [19].

7.3.2 Data recorded over time

Data within this category include historic records (e.g. of weather, and gaseous and particulate pollutants in the locality), results of laboratory or exposure tests (e.g. of the performance of a material under a particular test regime), characteristic data on materials and observations of *in situ* performance (e.g. maintenance records or condition surveys).

The relevance and reliability of the records should be assessed. The objective is to determine whether the data are indicative of the likely future performance of the building or component under assessment. The adequacy of reporting is critical.

NOTE Anecdotal evidence of performance is less reliable than scientific evidence, but may be all that is available. Partial reporting of data also occurs where commercial interests are involved (e.g. a supplier describes successful exposure results but suppresses negative results). However, the situation should improve as databases grow and criteria are established for the scope and quality of data to be supplied by manufacturers. The situation could improve further with the establishment of computer-integrated knowledge systems and standards governing interpretation of exposure data concerning performance over time.

Whatever the origin of the performance records, the objective is to identify the rate of degradation which occurs and how long it will take before performance falls below acceptable levels. The rate of degradation should correlate with the severity of exposure in the environment.

7.3.3 Comparison between exposure data and other evidence

An essential part of the data interpretation is judgement of comparability. Comparisons between different exposures, between rates of change in similar materials and between different environments are complicated. Ideally, expert interpretation should be sought but generally it is possible to interpret whether exposure to agents, relative intensity and frequency of cycling are greater or less than anticipated for the proposed building.

Caution should be used by the non-expert, particularly in interpretation (e.g. whether all relevant agents and mechanisms have been tested).

NOTE One problem with observations *in-situ* is that agents (e.g. weather conditions) may not be reported or be typical and therefore results may not reflect comparable conditions.

8 Service life prediction based on exposure and performance evaluation

8.1 Use of predictions based on exposure and performance evaluation

This clause describes, in outline, a systematic approach to selecting, obtaining and using service life prediction data to forecast the service life of a specific material, component or assembly. More detailed guidance on testing is included in ISO 15686-2. This is to assist the designer to commission or interpret testing carried out by experts. Interpretation of such results by non-experts should be avoided if possible.

The service life prediction applies to a defined set of conditions. Provided the conditions are known, relevant and complete, at least for the most important agents in comparison to those expected for the specific object to be designed (which is rarely the case), a service life prediction derived from exposure and performance evaluation may be used without further modification. Otherwise a modification will be required, which can be accomplished by the factored method (described in clause 9) or by other more sophisticated methods if available. Note that service life predictions generally do not take all the aspects included in the factor method into account (e.g. use and maintenance). However, a service life prediction based on exposure tests will normally provide the reference service life for a factored estimate. The most reliable available method, with the best data and certainty should be used.

For service life planning by a designer, it is normally necessary to interpret exposure data to give an estimate of service life based on factors. Service life prediction data rarely exist to cover all the unique applicable agents and conditions (including the effects of the total local environment, levels of workmanship realistically achievable on site, and effects of maintenance, use, etc.). Service life prediction data may therefore be viewed normally as an input to forecasts of performance rather than a final judgement.

NOTE Design of exposure and evaluation of performance data requires specialist expertise. Tests are normally commissioned by manufacturers or as part of research or feasibility projects. They typically need to be commissioned well in advance of detailed design and specification for a project, since even accelerated exposure is time-consuming. Therefore, for most designers, research into possible specifications is limited to data which already exists when design commences. While this usually describes reactions to single agents or to dissimilar environments to the project under consideration, it will nevertheless help in identifying relevant degradation mechanisms.

8.2 Steps in the prediction process

8.2.1 General approach

NOTE 1 The prediction process involves analysis of the problem under study and the gathering of relevant information and knowledge, as well as the use of tests and the comparison and interpretation of exposure and evaluation data. The general approach is summarized in Figure 4 (taken from ISO 15686-2).

NOTE 2 The subjects below are dealt with in detail in ISO 15686-2, which should be used as the appropriate and up-to-date guidance on this topic.

The design of exposure and evaluation are undertaken by specialists.

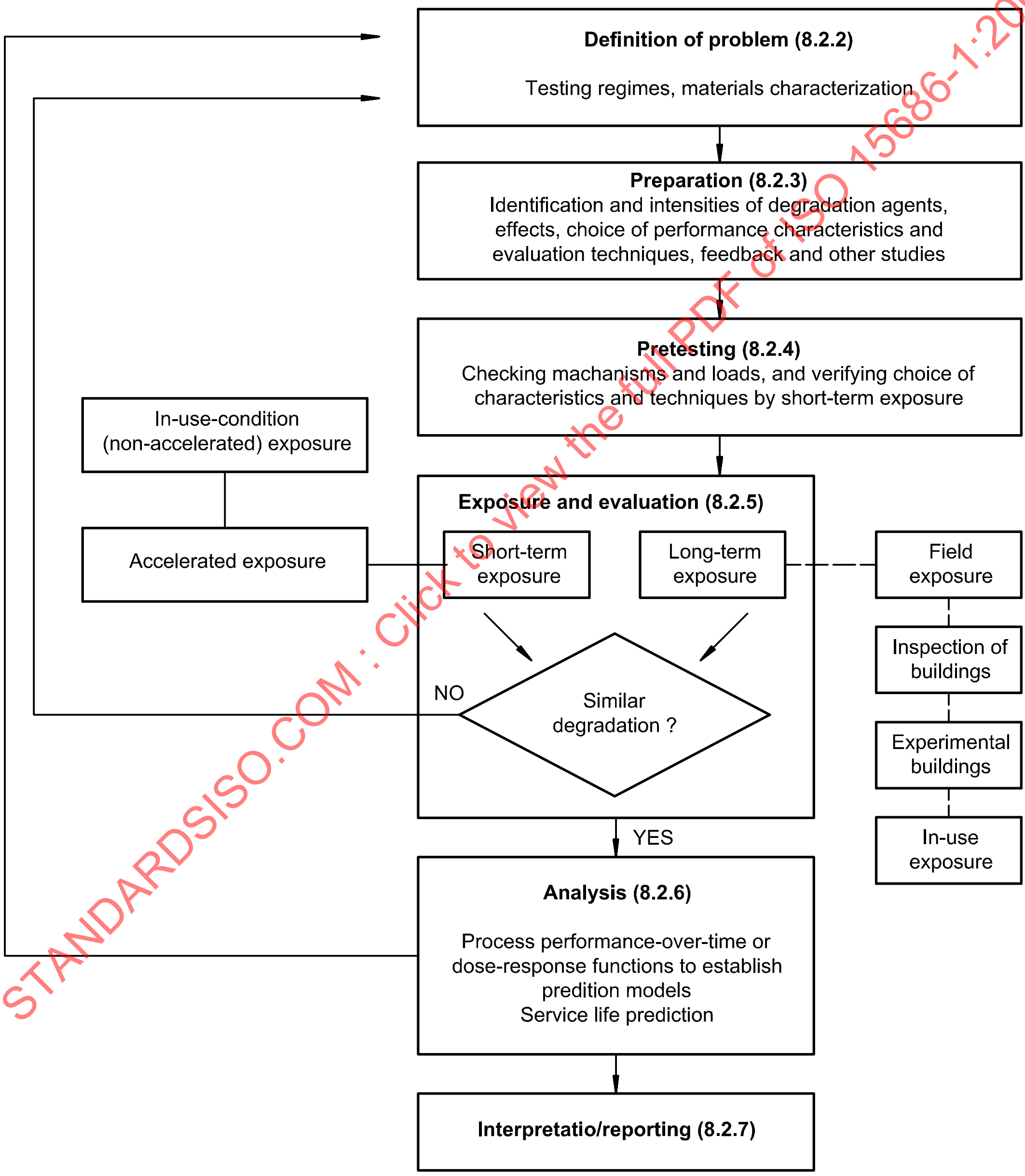


Figure 4 — Systematic methodology for service life planning of building components

8.2.2 Defining the problem

The first step is to analyse the problem, identify all the relevant factors and obtain the relevant information and knowledge. The actions required can be summarized as follows:

a) specify what functional performance is expected to be provided by the item under study irrespective of the building context (e.g. safety, durability, convenience, economy);

b) identify the building context that will apply (e.g. climate, conditions created by occupancy, the principles on which the building is operated, the design consequences of the built form such as exposure, interfaces, etc.); the type and range of agents of degradation must be identified;

c) identify the performance requirements for the item under study (e.g. strength, insulation, appearance);

d) select the performance criteria;

e) characterize the component or material in terms of chemical composition, structure and relevant requirement values (e.g. thermal transmission).

8.2.3 Preparation

The second step is to consider how degradation will take place under the particular conditions identified. This should involve identification of the following:

a) the agents which will cause degradation, classified as mechanical, electromagnetic, thermal, chemical or biological agents (see annex C); an attempt should be made to quantify the intensity, concentration, level, frequency and or maximum and minimum values of agents such as temperature, exposure to UV light or presence of pollutants;

b) the possible degradation mechanisms by which degradation agents could induce changes in the properties of the item under consideration (e.g. chemical reactions, shrinking, swelling);

c) the measurable effects of degradation;

d) the methods by which compliance with the criteria can be determined.

Using these identified agents and mechanisms, a test can be tentatively proposed in which degradation is induced by the same factors and mechanisms, thus allowing the effects identified to be assessed.

8.2.4 Pretesting

Pretests are a way of checking that the testing proposed will be likely to produce reliable results. They can point the way to adjustments and improvements in test procedures. Pretesting involves exposing the item to more extreme or more rapid action by degradation agents to provide a better understanding of the effects of varying doses and intensities and combinations of agents.

8.2.5 Exposure and evaluation

The testing of degradation may be by observing and measuring

— long-term degradation under in-use conditions and

— degradation under exposure conditions designed to accelerate the degradation effects of agents causing degradation.

Normally the two test methods are used in combination. The long-term, in-use observations serve to check the realism of the effects resulting from the accelerated exposure and will also normally identify actions relevant to adjacent materials.

The ways to generate data on long-term ageing under in-use conditions are as follows.

a) By field exposure: it is essential to record conditions during the test as well as the effect of those conditions, as the results will be specific to one location and one period, neither of which may be typical or relevant. As the results will be specific to one location and one period, recording will facilitate extrapolation to other locations.

b) By inspection of buildings: the usefulness of data from inspection may be limited by the difficulty of obtaining data on the history of the building, on the performance of the item being considered, and the difficulty of describing the environmental conditions and in-use conditions.

c) By experimental buildings: buildings designed to expose specific materials and components can provide information on performance of large-scale assemblies and, when part of a large-scale programme, can provide data on reliability.

d) By in-use exposure: items can be exposed to use in a building that has not been specifically designed for experiment. This approach is necessary where degradation is directly related to user action and behaviour. The aim of this method should be to create a situation that is as controlled as possible.

NOTE Test methods in the past have not always adequately considered the synergistic influence of current atmospheric pollutants, or may not reflect changing atmospheric conditions (e.g. greater exposure to UV).

Short-term exposure is carried out over a time period considerably shorter than the anticipated service life. Typically this is a fairly rapid way to obtain data for an assessment or prediction of the service life of a new product. A short-term test may include operating at higher intensities of one or several agents (accelerated exposure) or only be based on a shortened exposure period but with controlled exposure conditions. In cases where property changes leading to degradation can be detected at an early stage, the exposure may not need be designed to use more intense or more frequent degradation factors. It may involve similar agent intensities and frequencies to those in a field exposure but involve only those agents for which data is required (e.g. exposure to high temperature or humidity).

Accelerated tests involve the exposure of items to more intense or more frequently applied agents than are encountered in real situation (e.g. more intense cold, more frequent freeze/thaw cycles). They can provide a relatively rapid means of assessing the long-term change of properties. Accelerated exposure is usually designed from information obtained in pretests but should have lesser general intensity of degradation factors to reduce the likelihood of degradation being caused by mechanisms not encountered in real situations. Such tests are normally designed by experienced material scientists or materials engineers.

8.2.6 Assessing the data from exposure

If well-documented and applicable data are available from long-term exposure, the results should be compared with results from short-term exposure. Inconsistencies should be used to increase understanding. If there is little or no correlation between the results, the data should be re-examined and the design of the accelerated or short-term tests may need to be altered (or the field test may be misleading).

8.2.7 Interpretation and reporting

An essential part of data interpretation is judgement by experts. The significance of comparisons between different tests of rates of change in similar materials and components and between different environments must be assessed by an expert before a prediction of service life can be made. The report should be in a form which includes explicit statements of the assumptions made and the qualifications of the expert.

9 Factor method for estimating service life

9.1 Outline of the factor method

This method allows an estimate of the service life to be made for a particular component or assembly in specific conditions. It is based on a reference service life (normally the expected service life in a well-defined set of in-use conditions that apply to that type of component or assembly) and a series of modifying factors that relate to the specific conditions of the case.

EXAMPLE If the reference service life of a window is 20 years, a modifying factor of 0,8 might be used to estimate the window's service life in an exposed position. The estimated service life would then be 20 × 0,8 = 16 years. But if a particularly rigorous inspection and maintenance regime were to be applied to ensure that minor defects did not develop into more serious problems, then a further modifying factor of 1,4 might be applied. The estimated service life would then be 16 × 1,4 = 22,4 years.

Note that factors of less than 1 reduce the estimated service life and factors of more than 1 increase it.

The reliability of the reference service life figure is critical, as it will affect the estimate proportionally.

This method uses modifying factors for each of the following:

- factor A: quality of components
- factor B: design level
- factor C: work execution level
- factor D: indoor environment
- factor E: outdoor environment
- factor F: in-use conditions
- factor G: maintenance level.

Any one (or any combination) of these variables can affect the service life. The factor method can therefore be expressed as a formula:

ESLC = RSLC × factor A × factor B × factor C × factor D x factor E × factor F × factor G

Annex E summarizes the factors and what is included within each.

9.2 Use of the factor method

The factor method is a way of bringing together consideration of each of the variables that is likely to affect service life. It can be used to make a systematic assessment even when reference conditions do not fully match the anticipated conditions of use. Its use can bring together the experience of designers, observations, intentions of managers, and manufacturers' assurances, as well as data from test houses.

Not all components will need forecasts based on a factored estimate, and the project team and the building owner should agree which components are to be assessed on the basis of their criticality to use and cost of the building.

The factor method does not provide an assurance of a service life: it merely gives an empirical estimate based on what information is available. It is different from a fully developed prediction of service life (as described in clause 8), which will ideally provide the reference service life for a factored estimate. The distinction between estimated and predicted service life should be made when a forecast of service life is given. The information taken into account should also be recorded, so that it is clear whether the estimate is particularly robust or not.

Certain parties involved in building projects may be concerned about liability for forecasting future performance. For the avoidance of doubt, the recommendations of this part of ISO 15686 are not intended to implement contractual liabilities and the expectation is that "best efforts" will be applied, but that forecasts cannot be expected to always be either accurate or precise.

It may be desirable to consider the consequences of failure when estimating service lives using the factor method. It may be used as a guide both to those components which should be included in estimates (it may not be necessary to estimate every component's service life) and in deciding those where failure would be most critical. The method itself does not indicate the seriousness of failures, but interpretation of results may suggest components which are too "risky" to be used without either enhancing the specification or providing for regular condition monitoring. For these it may be necessary to be extra cautious, either by critically reviewing (and possibly changing) the design life (the "target") or typically by being particularly rigorous in assessing the value of factors.

The factor method can be applied to both components and assemblies. When applied to assemblies it is necessary to consider the interfaces (e.g. joints) between components as well as the components themselves. For example, different external environment and maintenance factors may apply to a whole assembly that relies on sealants to weatherproof the joints between factory made cladding units than those which would apply to each of the individual cladding units.

NOTE Annex F shows how the method may be used to assess alternative specifications, using typical UK conditions.

9.3 Reference service life

The starting point of the factor method is the reference service life. It is a documented period in years that the component or assembly can be expected to last in a reference case under certain well-defined service conditions. It may be based on the following:

a) data provided by a manufacturer, a test house or an assessment regime (for innovative components it will normally be based on the manufacturer's or supplier's exposure results); this may be a single figure or a distribution of typical performance;

b) previous experience or observation of similar construction or materials or in similar conditions;

c) Boards of Agreement in the EC state assessments of durability in their certificates or reports of national product evaluation services;

d) some books which are available and which include typical service lives;

e) building codes which may give typical service lives for components.

Wherever possible it should be as reliable and as detailed as possible, and thus preferably based on a service life prediction, as outlined in clause 8 and fully described in ISO 15686-2 The reference case from which the reference service life is taken should be as similar as possible to the specific case in terms of service conditions. The factors are applied to represent deviation from the assumed conditions in the reference service life. Thus the values of factors will be as close to unity as possible, thereby minimizing the uncertainty inherent in the factor method.

When the reference service life is provided by a manufacturer or other organization, it may be necessary to establish what conditions it is based on (e.g. if figures for a steel bath are based on domestic use they may not apply under more intensive use in an institution). Those who provide guidance on the reference service life of a category or class of component or of a type of construction should say in what conditions the figures apply.

Factors already included in the reference service life (e.g. variability of material in a laboratory test, or effects of poor maintenance where the reference service life is obtained from observation of *in-situ* performance) should not be taken into account again in the factors. Similarly, it is important to know whether the reference service life is pessimistic (e.g. based on time to first failure) or optimistic (e.g. based on mean time to failure). The estimated service lives which result from the application of factors will be affected.

NOTE Reference service lives are not defined in this part of ISO 15686. It is anticipated that national and international guidance will be developed through collaboration between owners, suppliers, materials specialists and constructors. This will permit typical performance and assumed conditions to be provided, with guidance on the assumptions made, which is necessary for applying modifying factors. ISO 15686-4, which will deal with data formats, should be of assistance.

9.4 Modifying factors

9.4.1 Choice of values

The choice of values to use as modifying factors may also be based on previous experience. If the conditions prevailing in a specific case have led to early failure or to an extended service life, similar conditions elsewhere may be used as the basis for applying a modifying factor.

EXAMPLE The service life of carpet in an entrance hall may have been found to be 25 % less than the carpet in general circulation areas. This observation would justify an operating characteristic factor of 0,75.

9.4.2 Assessing the overall contribution of individual factors

A combination of small modifying factors can have a significant effect overall. It is therefore essential to keep the overall picture in view when applying a series of these factors. The advantage of the factor method is that it allows everything that is likely to contribute to variations in service life to be examined at the same time and the relative importance of each to be considered and documented. This is especially important when degradation is affected by a combination of factors (e.g. poor workmanship and exposure to driving rain). Separately these factors may have little impact on the service life but taken together they are likely to lead to failures. Where two or more agents acting together have a negative or enhancing effect disproportional to either on their own, this should be considered in particular

EXAMPLE 1 Embrittlement of plastic rainwater drainage pipes due to UV degradation and likelihood of impacts during maintenance access may both lead to breakages, while both sheltering overhanging elements and painted protective coatings reduce this risk.

It is important not to “double-count” negative or enhancing factors under more than one heading. This can give an unduly cautious estimated service life.

EXAMPLE 2 If it is considered unlikely that site mixes of concrete will match the specification, this should be allowed for under either the materials factor or the workmanship factor, but not both.

NOTE In the Japanese guide [20] which was one of the originating works for this part of ISO 15686, several factors were “built-up” using known issues which each had a value which related to their known significance.

9.4.3 Data from which factors can be derived

Modifying factors will often be based on known actions of the environment on specific materials (e.g. increased corrosion in salt atmospheres), or on known effects of poor workmanship and maintenance. Manufacturers should be asked for details of agents that are likely to reduce or extend service life. Wherever possible the information should be given in a way that allows a figure to be selected as a modifying factor.

EXAMPLE The service life of a smoke alarm can be increased from 5 to 7 years by regular vacuum cleaning (which can be expressed as a modifying factor of 1,4 when a strict maintenance routine is operated).

Each factor represents the deviation from the assumed conditions when the reference service life was established.

9.4.4 Factor A: Quality of components

This factor represents the component as supplied to site. It is a measure of the quality of the design of the component itself.

EXAMPLE The specific softwood species, together with timber preservation, jointing and applied coatings for a softwood window where the reference value was for any softwood window.

9.4.5 Factor B: Design level

This factor reflects the component’s installation in the building and is based on whether the design of the building provides the installed component(s) with above-average shelter and protection from agents or confronts them

EXAMPLES An overhanging roof can provide extra protection to the wall below; a reflective coating can prevent cladding exposed to sunlight reaching a critically high temperature.

9.4.6 Factor C: Work execution level

This factor represents the level of skill and control likely in sitework. It is based on whether the sitework is likely to be in accordance with manufacturers' recommendations and tightly controlled. The assessment should be based on the likelihood of achieving the designed level of workmanship, including issues such as storage, protection during installation, ease of installation, number of trades required for each activity, site applied coatings, etc.

9.4.7 Factor D: Indoor environment

This factor indicates the environmental assessment (described in 6.5), the exposure to agents of degradation and their severity. The general use of the building should be taken into account within this factor, together with relevant local aspects (e.g. locations subject to wetting, such as kitchens and bathrooms). Once again it is the deviation from assumed conditions in input data that is measured by the factor.

NOTE 1 The EOTA document [19] contains tables of both internal and external environments, together with degradation agents to be taken into account for various materials.

NOTE 2 Internal and external environment are separated and for most components only one would apply, but certain components (e.g. those embedded in the building envelope) may be subject to degradation from both internal and external agents.

9.4.8 Factor E: Outdoor environment

A meso- or local-level designation may be adequate (e.g. coastal, polluted) for this factor. But for detailed design the microenvironment should be taken into account (e.g. southern elevation, wind suction or uplift at high-level, salt-spray zone). A combination of the agents can have a critical effect (e.g. a combination of wetting and freezing). Note also that components may be exposed both to external weathering and below-ground water.

9.4.9 Factor F: In-use conditions

This factor reflects the effect of use of the building. The specific use of the space where the component is installed or the assembly constructed is likely to be relevant (e.g. communal areas will be subject to greater wear and tear). External locations may also be relevant (e.g. delivery areas subject to mechanical impacts by vehicles). Again, the deviation from assumed conditions is measured.

9.4.10 Factor G: Maintenance level

Even though the forecast is made on the basis of a planned level of maintenance, the likelihood of that being achieved for the type of building under consideration should be included (e.g. certain components may be inaccessible or require special equipment for access). The expertise of cleaning should also be taken into account, as this may introduce agents not normally found (e.g. alkalis).

9.5 Assessment of components and assemblies

Table 3 shows the steps involved in planning the service life of components. The method relies on judgement and experience in the selection of values for reference service life and for each of the modifying factors. It also requires a critical examination of the overall result to ensure that a combination of values has not produced an unrealistic service life estimate, or life cycle cost.

Table 3 — Recommended steps to be taken in service life planning

Stage	Action	Typical responsibility (in UK)
Briefing/initial design (6.1, 6.2)	Agree which International Standard will be followed Identify DLB.(Table 1) Identify permanent components (where DLC = DLB) Identify critical performance requirements for major components (6.8)	Designer/client
COST CHECK		
Initial design/detail design (6.2, 6.3)	Characterize environment (6.5). Commence detailed design, and specification	Designer
COST CHECK		
Service life forecasting (clause 7) and assessment of test data availability and needs (clause 8)	Identify DLCs and RSLCs of major components Check data availability, relevance and completeness Check: which factors have been taken into account in RSLC? Check: do tests need to be commissioned (and timescale for results)? Should DLCs be adjusted for anticipated refurbishments?	Designer/supplier/test designer
COST CHECK		
Estimating service lives (clause 9)	Decide which components will have service life planned Identify DLCs and RSLCs for those components Check data availability Check: should DLCs be adjusted for anticipated refurbishments? Identify the modifying factors and values (clause 9) Multiply RSLC by factors to give ESLC Check: is ESLC > DLC? Check: does ESLC seem reasonable? If not, review design, installation detailing and site control or review DLC or review values for factors. Iterate until ESLC > DLC Check: has adequate caution been taken in evaluating ESLC for components which could cause danger if they fail during service?	Designer/supplier
COST CHECK		
Detailing site work (6.4.2)	Ensure written instructions to constructor match assumptions in estimates Check: Do site storage and installation on-site match assumptions in estimates? Review estimates where specification is changed/installation detailing is changed during construction period	Designer/constructor
COST CHECK		
Maintenance planning (6.7)	Provide details of estimated service lives and assumptions made about maintenance standards and frequency Provide archive report in a suitable format	Designer/client/user

10 Financial and environmental costs over time

10.1 General

A major incentive for planning the service life of the building and components is to enable planning of the cost of ownership. Estimating the future cost of running and maintaining the building gives clients advance notice of the cost of ownership, and allows them to reduce the financial risk of commissioning, purchasing or retaining a building, thereby assisting their business planning process.

Some examples of costs of building ownership are given in annex A.

In addition to the financial costs, buildings and their components are evaluated for their environmental costs. A balance needs to be set between production of building materials which may be environmentally damaging and the utility and durability of the buildings which are made from them. Reuse or recycling of materials, choice of less-damaging options and reuse of buildings are all options to consider.

NOTE 1 Historic costs are important to monitor, compare and validate predicted costs, but may not be accurate because of the pace of the introduction of new products and developing technologies.

NOTE 2 Very durable materials may cause problems in disposal since they are, by definition, resistant to the effects of normal weathering which cause degradation. However, they may be suitable for recycling.

10.2 Life cycle assessment (LCA)

Life cycle assessment (LCA) should not be confused with life cycle costing (LCC). It is a broader concept which entails identifying the “cradle to grave” resources consumed and/or effects on the environment throughout the service life of a product, such as a building (see ISO 14040). It is commonly used in considering sustainability of development but there are overlaps with life cycle costing. Each requires an assessment of what will happen over a prolonged period, and each may “count” replacements as relevant “costs” in provision of the building. There is therefore a complementary preference for components or materials with lower whole-life “costs” and reduced replacement or maintenance requirements. Both may also take into account the residual value when a material or component is reused or recycled. However, the optimum economic option may not have the least environmental cost.

10.3 Life cycle costing (LCC)

Life cycle costing (also known as whole-life or through-life costing) is a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs. Being able to compare the future costs of alternatives allows selection of the most economic overall design and helps planning and control of the cost of ownership. This subject will be covered in more detail in ISO 15686-5. Some essential features include the following.

a) Only designs and/or components which meet the design life, functional and performance requirements should be considered as alternatives.

b) Alternatives which meet the performance requirements but which have lower life cycle costs should be preferred.

c) LCC should be undertaken on the entire estimated service life of the whole building and its components and assemblies, or on a less-foreseeable service life.

d) All relevant economic factors, including opportunity costs (i.e. cost of choosing this investment rather than another), should be included within the analysis.

e) Initial costs include costs directly related to the whole building and its components and assemblies, including design, construction and installation, fees and charges.

f) Future costs include all operating (e.g. energy and cleaning), maintenance, inspection, replacement and demolition or removal costs.

g) Maintenance costs include costs of replacement, repair, refurbishment, disassembly and re-assembly. Planned cyclical maintenance and day-to-day maintenance as well as improvements and alterations should be included. An allowance should be made for unplanned remedial maintenance, based wherever possible on recorded historic costs and experience. Depending on the use of the building, costs associated with unavailability or provision of a replacement during maintenance work may also be required.

h) Timing of future costs should be taken into account in LCC [e.g. by discounting future costs to present day (PV) values].

i) Evaluation of alternative specifications may entail value engineering (VE) techniques.

NOTE Future parts of ISO 15686 may deal with life cycle costing and maintenance planning or profiling in more detail.

11 Obsolescence, flexibility and reuse

11.1 Obsolescence

Replacement due to defective performance should be distinguished from obsolescence. Obsolescence is due to inability to satisfy changing requirements. Reliable data for forecasting of obsolescence are rarely available. Estimation of the time to obsolescence should be based on the designer's and client's experience and if possible documented feedback from practice.

Obsolescence inevitably entails waste, since the building or parts which are still functional will be replaced. A secondary objective of service life planning is to reduce the likelihood of obsolescence and/or to maximize the reuse value of the obsolete building or components.

NOTE It may be desirable to consider components on the basis of the likelihood of their becoming obsolete within the design life of the building. Where this is considered highly probable, owners may wish to "build in" provisions for obsolescence, i.e. to allow for easy replacement in conjunction with other planned maintenance activities. The importance of service life planning is not reduced, but then becomes a matter of ensuring that performance remains acceptable for the reduced design life of the component.

11.2 Types of obsolescence

Obsolescence may be functional, technological, or economic. Replacements may also be made for reasons of changing fashion or tastes, but there is often an economic reason underlying such replacements (e.g. lettability of the building). Table 4 gives some examples of each type.

Table 4 — Types of obsolescence and examples

Type of obsolescence	Typical occurrence	Examples
Functional	Function no longer required	Obsolete industrial process, unnecessary facility, partitioning removed during remodelling of offices
Technological	Better performance available from modern alternatives/changing pattern of building use	Change from vitreous clay to stainless-steel sinks, change to open-plan layout in factories to allow installation of new plant, renewal of insulation for enhanced thermal performance
Economic	Fully functional but less efficient/more expensive than alternatives	Replacement of sectional boilers with condensing boilers

11.3 Minimizing obsolescence

Economic obsolescence occurs because maintenance has become unreasonably costly or disruptive, and when acceptable (cheaper) alternatives to maintenance are available. Maintenance (including replacements of components) should be anticipated at the design stage.

Items to be considered in particular are those where access costs are high (e.g. where scaffolding is required) or where normal use of the building has to be suspended (e.g. replacement of a factory floor).

Refurbishment and upgrading are the major strategies to counter obsolescence.

The most efficient designs will be flexible, and allow for some changes in future requirements. The risk of obsolescence will be reduced by designs which permit internal replanning, extensions, changes in service systems or changing partitioning of the building, but at a cost.

This may be particularly relevant to offices, and the building frame or structure should be considered in particular. Strategies include allowing different floors to be let separately, and generous supply of building services and sanitary facilities and fire escape routes.

11.4 Future use of the building

A building is generally a very durable capital asset, and the initial client may only have a limited foreseeable use for it. Service life planning can allow for future sale or reuse by subsequent owners, thereby increasing the residual value of the building. Extending the service life of the building and reducing component maintenance and replacements also contributes to achieving sustainable development and preservation of scarce resources.

11.5 Demolition and reuse

Demolition of the building should be taken into account even at the design stage, in order to reduce waste and facilitate reuse of materials or components if it is appropriate at the end of the service life of the building. This may also be a requirement of local building codes covering safety of building work.

NOTE 1 Matching the component service lives to that of the building reduces the waste at demolition. This is particularly important for temporary buildings.

NOTE 2 The ability to separate the components leaving uncontaminated materials is essential to recycling.

Annex A
(informative)

Typical financial costs of buildings over time (in UK and USA)

In developed economies, approximately 50 % of spending on construction is accounted for by maintenance (including refurbishment), and maintenance costs per annum may amount to 3 % of the initial capital cost of the building. Various governments (including the UK and the USA) have recently set targets for reducing the need for expensive maintenance through increasing durability and flexibility and reducing operating costs (including energy costs).

The following figures were taken from reports by Building Maintenance Information for the UK and from an overview of the US construction industry by the Civil Engineering Research Foundation.

Nearly 50 % of all construction output in the UK is spent on repair and maintenance (BMI Report 244, 1995, Table 9). Total spending on building maintenance in the UK has increased by 66 % in the last 10 years (BMI Report 253, 1996). It now represents over 5 % of Gross Domestic Product, or £36 000 million (BMI Report 254, 1996).

An average of 22 % of occupancy costs in the UK are spent on building maintenance, including decoration, fabric and services (BMI Report 234, 1994, Table 1).

In the USA about 13 % of Gross Domestic Product (as at 1996) is spent on construction, and about 40 % or $342 billion of that is on maintenance and refurbishment. A 50 % reduction in operation, maintenance and energy costs and a 50 % increase in durability and flexibility have been set as industry targets

In the UK, annual maintenance of a building costs an average of about 2 % of its initial capital cost (BMI Report 244, 1995). Refurbishment costs between 54 % (banks) and 82 % (flats) of the initial capital cost (BMI Report 252, 1996, Table 1).

Some building types (e.g. shops and offices) are refurbished every 10 years or so.

Once improvements are taken into account, work to existing buildings may cost 5 % of the capital value of the national building stock every year.